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THE MANUFACTURE OF ICE CREAM

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THE MANUFACTURE OF ICE CREAM

Introduction

Ice cream has gradually developed from a home-made and confectioners' product to one that is manufactured on a wholesale scale by dairy plants. The introduction of power brine freezers and mechanical refrigeration, as well as other ice cream equipment, gave a tremendous impetus to the industry and was really the starting point for the marked growth of the wholesale manufacture of ice cream. To-day the ice cream business is an important branch of the dairy industry in Canada.

The volume of production had increased steadily until in 1929 a total of 9,797,436 gallons of ice cream were manufactured with a value of $13,604,709. During the succeeding four years, however, production decreased with the decline in general business conditions, and in 1933 the gallonage and value were less than half of that in 1929. Since 1933 the total gallonage of ice cream manufactured has increased steadily and in 1937 amounted to 9,367,191 gallons with an estimated value of $11,552,188, according to reports of the Dominion Bureau of Statistics. Figures for the per capita consumption of ice cream and other dairy products indicate that ice cream consumption fluctuates more with general prosperity than consumption of other dairy products. This is no doubt due to the fact that ice cream is still considered as a confection and a luxury by many consumers.

The development of the ice cream industry has been accompanied by a continual and general improvement in the quality of ice cream, due to better methods of manufacture. The growth of the business has brought new problems and conditions for the manufacturer. The consumer is more discriminating in his taste, and competition is keener hence there is need for good equipment and an understanding of the principles of ice cream making if the operations of the plant are to be successful.

It is the purpose of this bulletin to explain some of the important factors in the production of a good quality ice cream.

The Food Value of Ice Cream

One of the important factors in stimulating the consumption of ice cream has been the wide publicity given regarding the food value of all dairy products. The results of nutritional investigations undoubtedly have brought to the attention of the consuming public the fact that ice cream is a very desirable and healthful food. Thus it is accorded a regular place in the dietary of public dining rooms, restaurants, hospitals, and many homes.

Although containing other products, ice cream is classed as a dairy product, and contains the four essential food substances naturally found in milk, namely, fat, proteins, carbohydrates and mineral matter. As a result, ice cream supplies the important protective and auxiliary food substances known as vitamins. Milk fat is one of the most digestible of the edible fats and oils, and is one of the best natural sources of the valuable vitamin A and an important source of vitamin D. Milk proteins have a high nutritional and digestible value and are a good source of vitamin B as well as containing some of vitamin C. The carbohydrates or energy-producing substances are plentifully supplied in ice cream

by the milk sugar and the added cane sugar. The mineral content is high, especially in calcium and phosphorous salts which are so essential to the development and growth of strong bones and teeth.

Average commercial ice cream contains between 36 and 40 per cent of highly digestible total solids, and compares favourably with most of the staple foods in energy-producing or caloric value. In addition to being highly nutritive, ice cream is one of the most palatable of foods, and is relished by nearly all people, whether old or young, ill or healthy.

Classification of Ice Cream

While there has been no classification of ice cream accepted as standard by the industry, several classifications (1, 2, 3, 4) have been suggested according to the ingredients and flavours used. In commercial practice there is no hard and fast rule as to ingredients used in ice cream of different names, and it is, therefore, difficult to group the ice creams by ingredients only. Mortensen (1) divided the various frozen products classed as ice cream into ten groups and Sommer (5) has used Mortensen's classification with some slight modifications. This latter classification is as follows:—

1. PLAIN ICE CREAM.—Made from various dairy products and sugar, with or without gelatin or other stabilizer. Eggs are sometimes used in the form of fresh eggs or as egg yolk powder. This type of ice cream is frozen with a single flavour such as vanilla, chocolate, caramel, coffee, mint or maple.
2. NUT ICE CREAM.—Made from the same mixes as used in plain ice cream with the addition of walnuts, almonds, chestnuts, pistachio, etc.
3. FRUIT ICE CREAM.—Made from the same mixes as plain ice cream with the addition of strawberries, peaches, pineapple, etc., at the time of freezing.
4. BISQUE ICE CREAM.—Made from the same mixes as for plain ice cream with the addition of macaroons, marshmallows, grapenuts, etc., and generally with other flavouring materials.
5. MOUSSE.—Made from rich whipped cream that has been sweetened and to which different flavours are added. This product is frozen with very little agitation after the cream has been whipped and the flavour added.
6. PARFAIT.—Made from mixes similar to or richer than the plain ice cream but with the addition of eggs, usually in the form of egg yolk, to give a distinct yellow colour. Different flavourings and fruit may be used.
7. PUDDING.—While there is no uniformity in composition of puddings made commercially, this type of ice cream should be made from a rich parfait mix containing egg yolk with the generous addition of a mixture of fruits in fresh and candied form. Frequently nuts and spices are added.
8. CUSTARD.—This type of ice cream is usually made from a custard base containing milk, eggs and starch. Cream, sugar and flavouring are added and the mixture frozen. Real custards are not commonly made in commercial plants.
9. ICE.—Made from water, sugar, fruit juices with colour, fruit flavouring and a stabilizer usually added. Ices frozen to a slushy consistency and served in that form are known as frappes. If alcoholic liquor is used in place of part or all of the fruit juices the ice is known as a punch.
10. SHERBET.—Made by using milk, cream or ice cream mix to replace part or all of the water as used in ices. A sherbet made with the addition of egg yolks is known as a souffle. A sherbet made with sour or cultured milk (starter) is called "Lacto" (6).

The Ingredients of Ice Cream and their Sources

Commercial ice cream contains a number of ingredients which are obtained from a variety of sources. These ingredients and the products from which they are obtained are enumerated as follows:—

MILK FAT.—Most of the milk fat in ice cream is obtained by the use of fresh sweet cream, or when sweet cream is scarce, by using unsalted butter. Some fat is supplied by whole milk, condensed milks, evaporated milk and milk powders when these products are used. The amount of fat present in skim-milk products, however, is so small that it is not taken into consideration.

Where fresh sweet cream is scarce or high in price during certain seasons, cream is stored quite frequently as frozen cream during the season when the supply is plentiful and prices low. When cream is frozen for storage only the very best quality should be used, all cream should be pasteurized at a temperature of 150° F. for 30 minutes at least, and care should be taken to eliminate the presence of copper or iron salts. Frozen cream should be stored at a temperature of 0° to -10° F. in light weight, straight sided tinned cans of 50 to 60 pounds capacity.

MILK SOLIDS NOT FAT.—All dairy products contain milk solids not fat, but in addition to the sweet cream or whole milk that is used, it is necessary to add additional milk solids not fat by using one or more of the various products that contain a high percentage of this ingredient. Such products as sweetened or unsweetened condensed milk either whole or skim, evaporated milk, and whole or skim-milk powders are used for this purpose with equally good results, provided they are of good quality and handled and proportioned properly in the mix. Market conditions, price and the quality available are factors which influence the selection of these materials.

SUGAR.—Cane or beet sugars in the granulated form are used in ice cream. However, when these sugars are high in price or the supply scarce, glucose sugar may be used to supply part of the sugar requirements. In some places glucose sugar is sold under the trade name of cerelose. According to Combs (7) this sugar is only about 74 per cent as sweet as cane or beet sugars, known as sucrose, and should only replace about 35 per cent of the sucrose. Under the Food and Drugs Act of Canada it is illegal to use any sugar but sucrose in ice cream.

Sweetened condensed milks contain approximately 40 per cent of sugar, and when used the sugar they contain will have to be taken into account when making up the mix.

GELATIN.—This is the stabilizer most generally used in ice cream. It is a colloidal substance obtained from animal bones and tissue which will dissolve in hot water and on cooling will form a jelly. Only gelatin prepared for food purposes should be used and it should have a clean, inoffensive odour. Gelatin is prepared for the market in the form of sheets, shreds or powder, the latter being the most popular form for ice cream.

Gelatins differ greatly according to grade. In a study of gelatins by the Division of Bacteriology and Dairy Research (8) it was found that there was as much as 100 per cent variation in gel strength between different brands and grades of gelatin. The cheapest gelatin on cost per pound basis was not the cheapest on a gel strength basis. Gelatins for ice cream making should be purchased on a quality basis, especially for gel strength.

OTHER STABILIZERS OR IMPROVERS.—Vegetable gums, ice cream improvers and starch are sometimes used to supplement or replace gelatin as an ice cream stabilizer. The most commonly used vegetable gums are gum tragacanth and India gum. They will absorb many times their own weight of water and only

small quantities are necessary. They are seldom used in present methods of manufacture. Starch acts in much the same manner as the gums and is only used when true custards are made. Ice cream improvers have little place in modern ice cream making. They tend to improve unhomogenized mixes of low solids but have the disadvantage of unknown composition and are relatively expensive.

EGG PRODUCTS.—Frequently egg products are used now in the plain ice cream mixes as well as in the richer mixes used for parfaits, puddings, etc. They may be used in the form of fresh or frozen eggs or as powdered products. The frozen product is a mixture of both the whites and yolks or of yolks themselves which have been thoroughly beaten together and frozen. The powdered products may be obtained as powdered whole eggs, powdered whites and powdered yolk. It requires one dozen eggs to yield 0·25 pounds of powdered egg yolk or 0·33 pounds of powdered whole egg.

FLAVOURING MATERIALS.—The most popular flavour for plain ice cream is vanilla. This extract is made by dissolving in alcohol the pure essence of the vanilla bean. Although there are several varieties of vanilla bean, the best extract is produced from the best grade of Mexican beans. Inferior extracts are made from the poorer grades of Mexican beans, and other varieties or by adulterating the pure extract with artificial vanillin. Orange and lemon flavour extracts are produced by dissolving the pure oils of these fruits in alcohol.

Fresh or preserved fruits of practically every kind are used for flavouring fruit ice creams, while clean, sound, non-rancid nuts are used for nut ice creams.

Other flavouring materials used are macaroons, grapenuts, cakes, etc., for what are known as bisque ice creams.

Chocolate flavouring is made by making a syrup of sugar and either the bitter chocolate or cocoa, by using one and one-half pounds of bitter chocolate or one pound of cocoa with two pounds of sugar. The chocolate or cocoa is mixed with the sugar and enough water or milk is added to make a thick syrup, then heated in a double boiler until the syrup is smooth, and cooled before adding to the mix. This quantity is sufficient for ten gallons of ice cream.

WATER.—All ice cream mixes contain between approximately 58 and 64 per cent of water. In most mixes this water is present as a normal constituent of the milk or other products, but in some cases additional water will have to be added to the mix to obtain the desired proportions of fat and total solids.

The Relation of the Ingredients to the Quality of Ice Cream

The various ice cream ingredients are used for definite purposes and each plays a very important part in determining the quality of the finished product. The function of each ingredient is as follows:—

MILK FAT.—The flavour and the palatability of ice cream is largely determined by the milk fat or the milk product that supplies most of the fat. It has been demonstrated many times that nothing can take the place of fresh sweet cream as the basic milk product in ice cream. Cream of good quality gives a rich delicate flavour to the ice cream that cannot be obtained by the use of substitutes such as butter. The amount of milk fat also determines largely the food value of the ice cream as this ingredient is rich in vitamins and heat units.

MILK SOLIDS NOT FAT.—These constituents of milk products bear a very important relation to the texture and body of ice cream and the overrun obtained. Too much milk solids not fat tends to produce a heavy, soggy ice cream and may cause sandiness, while too low a proportion gives a light fluffy

body and makes it difficult to obtain overrun. In the proper proportions, milk solids not fat improve the texture and body of ice cream and increase the nutritive value as they are rich in proteins and the water-soluble vitamins.

SUGAR.—Primarily this ingredient is used as a sweetening agent to increase the palatability of the ice cream, but it also increases the food value. Sugar influences the freezing point of the ice cream more than any one other ingredient. A high sugar content lowers the freezing point to such an extent that it is more difficult to freeze the mix and keep it frozen.

GELATIN.—Gelatin is used in the ice cream mix to produce a smooth-textured product. Because of the ability of gelatin to absorb large quantities of water, it helps to prevent the formation of large ice crystals during freezing and retards the development of a coarse texture due to fluctuating temperatures in retail cabinets. Gelatin also increases the melting resistance of ice cream. Gelatin has some food value in itself and is important because it aids in the digestion and assimilation of the other food constituents such as proteins.

EGG PRODUCTS.—Egg products act as a stabilizer in much the same way as gelatin and, as such, improve the whipping properties of the ice cream mix. Egg yolk is the important part of the egg in this regard. Eggs also improve the texture of the ice cream and although they may impart a slight egg flavour to the finished product this is not an objection in most localities. When dried egg yolk is used, 0·25 to 0·50 per cent is sufficient in the plain mixes.

FLAVOURING MATERIALS.—Flavouring extracts have an important influence on the delicacy and palatability of the finished ice cream. It is necessary therefore, to use care and judgment in the selection of the flavour extracts. The amount of flavouring material used in ice cream is so small that the difference in cost per gallon of ice cream between a good and poor extract is a negligible matter. The manufacturer who wishes to establish a reputation for high quality ice cream cannot afford to use anything but the best of flavouring materials whether extracts, fruits or nuts.

Composition of Ice Cream

The composition of the ice cream mix will depend on the legal standards, the preferences of the consuming public for which the ice cream is made, and the opinion of the manufacturer as to the best proportions of the various ingredients. All ice cream must meet the required minimum legal standards for milk fat and total solids, but the exact proportions of fat and other ingredients will depend on the quality of the product desired and the basic formula of the individual manufacturer.

Several studies have been made to obtain the opinion of the consumer as to the best composition for ice cream. These studies were made by giving representative consumers a choice of ice creams of various compositions over a period of several weeks and recording their preferences. Williams and Campbell (9) and Depew and Dyer (10) found that consumers preferred ice cream with a fat content of 16 to 18 per cent to that which had a fat content of 8 to 12 per cent. Consumers also preferred ice cream with a solids not fat content of 10 to 12 per cent rather than the ice cream with low solids not fat. In both experiments the large percentage of consumers chose the ice cream with 16 per cent sugar in preference to ice creams of lower sugar content, and the ice cream containing 0·5 to 1·0 per cent gelatin was preferred to ice cream in which no gelatin had been used.

While an ice cream mix of 16 to 18 per cent fat and 16 per cent sugar would be considered as too rich for commercial ice creams, the experiments of consumer preferences indicate that the manufacturer should set a fairly high standard for the composition of his ice cream.

Combs (11) reported the results of a survey taken among representative plants in the United States. The average composition of the mix used in thirty-one of these factories is as follows:—

Butterfat	11·52	per cent
Milk solids not fat	10·52	"
Sugar	13·95	"
Gelatin	0·45	"
Total solids	36·46	"

The percentage of fat in the mixes varied from 8·5 to 14·2 per cent, while the milk solids not fat varied from 6·67 per cent to 13 per cent.

Published data on the average composition of Canadian ice cream are very meagre. James (12) published reports of analyses for fat and total solids of 28 samples of ice cream as sold in Winnipeg. These samples had an average fat and total solids content of 15·2 and 37·96 per cent respectively. The fat content varied from 12·0 to 18·4 per cent, while the range in total solids was from 32·72 to 41·71 per cent. The percentages of butterfat and total solids of eighteen samples of ice cream submitted in the ice cream classes at the Dairy Convention at Edmonton, Alta., in 1927 are reported by Kelso (13). These exhibition samples had an average fat content of 13·66 per cent with a maximum of 15·25 per cent and minimum of 12·4 per cent. The average percentage of total solids was 36·46 per cent with a maximum of 39·21 per cent and a minimum of 33·47 per cent. At the time these analyses were made all samples were well above minimum legal requirements.

During the past few years much unpublished information on the percentages of fat and total solids of Canadian ice cream has been accumulated from analyses made by the Division of Bacteriology and Dairy Research. For 846 samples of all kinds of ice cream analysed between December, 1935, and October, 1936, and which were representative of the ice cream of all provinces, the average fat and total solids contents were 14·21 and 39·79 per cent respectively. The fat content varied from 7·33 to 24·68 per cent and the range in total solids content was from 33·19 to 50·07 per cent. During the period from June, 1937, to June, 1938, 900 samples of ice cream of all kinds were analysed. The average fat content was 14·34 per cent and the average total solids content was 39·61 per cent.

The range in fat content was from 6·87 to 22·85 per cent while the total solids varied from 29·52 to 48·43 per cent. These analyses not only showed a wide range in the fat and total solids content of Canadian ice creams, but this variation was apparent in ice creams of the one kind from the same locality and in some cases from the same plant. Because ice cream is made from a number of different milk products with other added ingredients, and also because the ideas of ice cream manufacturers differ as to the composition of a basic ice cream mix that will suit their particular requirements, these variations in the composition of ice cream are to be expected.

However, the range in percentages of the principal ingredients in most Canadian commercial ice creams is usually within the following limits:—

Ingredient	Per cent
Milk fat (plain flavours)	13·0 -16·0
Milk solids not fat	8·0 -11·0
Sugar	13·0 -15·0
Gelatin	0·25- 0·5
Egg products	0·0 - 0·5
Total solids	37·0 -42·0

There are many combinations of the above percentages of the principal ingredients which, when properly handled, will produce a commercial ice cream of good body and smooth texture, and which will conform to Canadian standards

for butterfat and total solids. However, the proportioning of a mix that will meet the particular requirements as to cost, quality and consumer demand is a problem for each individual ice cream manufacturer to decide.

The composition of the mix having been decided and the materials selected, the next step is to proportion the materials so that the assembled mix will contain the different ingredients according to the standard decided upon.

Standardizing the Ice Cream Mix

An important factor in the production of good commercial ice cream is uniformity of product. It is important, therefore, that the ice cream mix should be standardized to the same composition of butterfat, milk solids not fat, sugar and gelatin from day to day so that the resulting ice cream will be uniform in quality.

To obtain uniformity in the composition of the mix, it is essential to know the composition of the various milk products and other ingredients used. The small plant generally does not have the necessary equipment to make an analysis of each product, and the maker will have to depend on the analysis given by the manufacturer. Milk products vary considerably in composition, and the composition of each new supply should be obtained.

The following table compiled from various sources gives the approximate composition of different milk products used in compounding an ice cream mix. These figures may be used when the exact composition of a dairy product is unknown:—

Approximate Composition of Various Milk Products and Other Ingredients Used in Ice Cream

Product	Per cent fat	Per cent M.S.N.F.	Per cent sugar	Per cent total solids
Skim-milk	....	9·0	....	9·0
Whole milk	3·0	8·73	....	11·73
"	3·5	8·68	....	12·18
"	4·0	8·64	....	12·64
Cream	20·0	7·13	....	27·13
"	30·0	6·24	....	36·24
"	40·0	5·35	....	45·35
Evaporated whole milk	8·0	20·0	....	28·0
Sweetened condensed whole milk	8·0	20·0	41·0	69·0
Condensed skim-milk (sweetened)	....	28·0	41·0	69·0
Condensed skim-milk (unsweetened)	....	30·0	....	30·0
Skim-milk powder	1·0	96·0	....	97·0
Whole milk powder	26·5	72·0	....	98·50
Butter (unsalted)	84·0	1·0	....	85·0
Granulated sugar	....	....	100·0	100·0
Gelatin	....	....	....	90·0

However, proportioning an ice cream mix is just a matter of standardizing the various dairy products used, and every ice cream maker should thoroughly understand such a procedure.

Acidity is another factor that is receiving attention at the present time in standardizing the ice cream mix. Some manufacturers are now making a practice of reducing the acidity of the mix to a uniform standard. When the acidity is only slightly high, such a practice may be justified in order to produce uniform quality. Under no circumstances, however, should such a procedure be used to try and cover up flavour defects from very sour or poor-quality products.

The normal acidity of the mix will depend on the acidity of the products used and also on the composition. The use of fresh dairy products of low acidity will produce a mix of lower acid than when the products have a high initial acidity. Also, a mix containing a high percentage of serum solids will

have a higher acidity than a mix with a low serum solids content. Dahle (14) found that the acidities for three mixes made from the same materials and with the same fat, sugar and gelatin content, were 0·17, 0·20, and 0·23 per cent when the serum solids content was 8, 10, and 12 per cent respectively.

The acidity of the ice cream mix should not be reduced lower than the average acidity which is natural for mixes made from good quality dairy products. For example, mixes containing 10·5 to 11 per cent serum solids and made from dairy products with an equivalent milk acidity of 0·18 per cent will have an acidity of approximately 0·22 per cent, and such mixes should not be neutralized.

When neutralization is practised, Sommer (5) recommends sodium bicarbonate for ice cream mixes. Stronger alkalis such as sodium carbonate or caustic soda are likely to produce soapy flavours, while lime and magnesia often leave bitter flavours and decrease whipping ability by inducing a more extensive clustering of the fat globules. In the neutralizing operations all acidities should be checked carefully by the acid test, and the neutralizer should not be used in excess of the amounts found necessary by calculation or from neutralizing charts. Information on the neutralization of cream is given fully in Publication 643 of the Dominion Department of Agriculture, Ottawa.

Calculating the Ice Cream Mix

A few examples of ice cream mixes are given to illustrate the different materials that are used and how to proportion them to get a mix of a desired composition.

EXAMPLE I.—A mix of 100 pounds is desired using only cream containing 18 per cent butterfat, sugar and gelatin. The mix is to contain 14 per cent sugar and 0·5 per cent gelatin. The first step is to calculate the number of pounds of sugar and gelatin to be used.

Sugar—14 per cent of 100 pounds = 14 pounds.
Gelatin—0·5 per cent of 100 pounds = 0·5 pound.

As the remainder of the mix is made up of cream, the number of pounds required for 100 pounds of mix is 100 — 14·5 = 85·5 pounds.

If this mix is tabulated, the amount of the various ingredients can be calculated, as the cream contains 18 per cent fat and approximately 7·38 per cent milk solids not fat.

Materials Used	Butterfat	Milk solids not fat	Sugar	Gelatin
85·5 lb. cream	15·39	6·3	....	....
14·0 lb. sugar	....	....	14·0	....
0·5 lb. gelatin	....	....	....	0·5
100·0 lb. mix	15·39	6·3	14·0	0·5

NOTE.—A simple method of calculating the approximate percentage of milk solids not fat in cream is to find the pounds of milk serum in the cream by subtracting the pounds of fat from the total pounds and multiplying by 9 and dividing by 100, or multiplying the per cent of milk serum by 0·09, as milk serum contains approximately 9 per cent of milk solids not fat.

For example: cream tests 20 per cent fat. This will leave 80 pounds of milk serum in every 100 pounds cream or there will be 80 per cent milk serum. This 80 pounds of the cream contains 9 per cent of milk solids not fat; therefore, 100 pounds cream contains

$$\frac{80 \times 9}{100} = \frac{720}{100} = 7{\cdot}2 \text{ pounds or per cent of milk solids not fat.}$$

It will be noticed that this mix is comparatively high in butterfat and low in milk solids not fat. Such a mix will tend to be rather light and fluffy in texture if sufficient overrun is obtained, and would not be considered as an ideal mix for commercial purposes.

EXAMPLE II.—In this mix of 100 pounds the following materials are used: cream, 20 per cent fat; sweetened condensed skim-milk containing 28 per cent milk solids not fat and 40 per cent sugar; sugar and gelatin.

The composition of the mix is to be as follows:—

15 per cent butterfat.
9 per cent milk solids not fat.
14 per cent sugar.
0·5 per cent gelatin.

The first step is to calculate the number of pounds of each ingredient that the mix requires:—

Butterfat..	15 per cent of 100 pounds =	15 pounds
Milk solids not fat..	9 per cent of 100 pounds =	9 pounds
Sugar..	14 per cent of 100 pounds =	14 pounds
Gelatin..	0·5 per cent of 100 pounds =	0·5 pound

In this mix all the butterfat is supplied by the cream, so the number of pounds of cream to use is found by dividing the pounds of fat required, which is 15, by the per cent of fat in the cream and multiplying by 100.

$$\frac{15}{20} \times 100 = 75 \text{ pounds cream.}$$

As the milk serum in the cream contains approximately 9 per cent milk solids not fat, the amount of this ingredient supplied by the cream is found by subtracting the pounds of fat (15) from the pounds of cream (75) and considering the remainder as milk serum.

$75 - 15 = 60$ pounds milk serum.
9 per cent of $60 = 5 \cdot 4$ pounds milk solids not fat.

The cream supplies 5·4 pounds of milk solids not fat but the mix requires 9 pounds of milk solids not fat, which leaves $9 - 5 \cdot 4 = 3 \cdot 6$ pounds of this ingredient to be supplied by the sweetened condensed skim-milk.

The condensed skim-milk contains 28 per cent milk solids not fat, so the quantity of sweetened condensed skim-milk required is

$$\frac{3 \cdot 6}{28} \times 100 = 12 \cdot 85 \text{ pounds of sweetened condensed skim-milk.}$$

This milk product also contains 40 per cent sugar and will therefore supply 40 per cent of $12 \cdot 85$ pounds $= 5 \cdot 14$ pounds sugar.

As the mix requires 14 pounds of sugar, the amount of this material to add is found by subtracting the amount of sugar supplied by the sweetened condensed skim-milk from the total pounds required, which is

$14 - 5 \cdot 14 = 8 \cdot 86$ pounds sugar.

The amount of gelatin required has already been calculated and is 0·5 pound.

If the mix is tabulated it will show as follows:—

Materials Used	Butterfat	Milk solids not fat	Sugar	Gelatin
75·0 lb. of cream	15·0	5·4		
12·85 lb. sweetened condensed skim-milk		3·6	5·14	
8·86 lb. sugar			8·86	
0·50 lb. gelatin				0·5
2·79 lb. water				
100·0 lb. mix	15·0	9·0	14·0	0·5

It will be seen from the above table that it was necessary to add 2·79 pounds of water to make up this mix to the required amount of 100 pounds.

EXAMPLE III.—A mix of 100 pounds is required from the following materials: cream, 40 per cent butterfat; skim-milk; unsweetened condensed skim-milk containing 30 per cent milk solids not fat; sugar and gelatin.

The desired composition of the mix is as follows:—

Butterfat	14	per cent.
Milk solids not fat	10	"
Sugar	14	"
Gelatin	0·5	"

The amounts of the different ingredients are next calculated as follows:—

14 per cent of 100 pounds = 14 pounds butterfat.
10 per cent of 100 pounds = 10 pounds milk solids not fat.
14 per cent of 100 pounds = 14 pounds sugar.
0·5 per cent of 100 pounds = 0·5 pound gelatin.

In this mix all the sugar is added as cane sugar and the amount required has been found to be 14 pounds. The amount of gelatin has been calculated as 0·5 pound. As all the butterfat is supplied by the cream, it will be necessary to add enough to supply the 14 pounds of fat required, which is

$$\frac{14}{40} \times 100 = 35 \text{ pounds cream.}$$

The cream will also supply some milk solids not fat. This is found by finding the pounds of milk serum and taking 9 per cent of that amount.

35 – 14 = 21 pounds milk serum.
9 per cent of 21 = 1·89 pounds of milk solids not fat.

It is necessary next to find the amount of skim-milk and unsweetened condensed skim-milk required to supply the remainder of the milk solids not fat. The milk solids not fat required are 10 pounds, while the cream supplies 1·89 pounds, which leaves 10 — 1·89 = 8·11 pounds of milk solids not fat to be supplied by the other milk products.

The total amount of materials for the mix so far is 14 pounds sugar, 0·5 pound gelatin and 35 pounds cream = 49·5 pounds. Therefore there are still 100 — 49·5 = 50·5 pounds of the mix to be supplied by the skim-milk and the unsweetened condensed skim-milk. These materials must also supply 8·11 pounds of milk solids not fat. This is equivalent to a milk solids not fat percentage in the standardized product of

$$\frac{8 \cdot 11}{50 \cdot 5} \times 100 = 16 \cdot 06 \text{ per cent milk solids not fat.}$$

To standardize a mixture of skim-milk with 9 per cent milk solids not fat and condensed skim-milk with 30 per cent milk solids not fat, Pearson's formula is used as given below:—

Unsweetened condensed skim-milk 30 per cent		7·06 parts of condensed skim-milk
	16·06 per cent	
Skim-milk 9 per cent		13·94 parts of skim-milk
		21·0

To standardize milk products by means of Pearson's formula, draw a rectangle and in the case of this illustration, place in the upper left-hand corner the per cent milk solids not fat in the unsweetened condensed skim-milk, and in the lower left-hand corner the per cent milk solids not fat in the skim-milk. In the centre place the per cent of milk solids not fat desired. Then subtract diagonally the smaller numbers from the larger one and place the figures at the right-hand corners of the rectangle. These figures are the proportions of the different materials to use.

In the mix under consideration, the unsweetened condensed skim-milk and the skim-milk will have to supply 50·5 pounds, therefore there will be

$\frac{7 \cdot 06}{21}$ of $50 \cdot 5 = 16 \cdot 98$ pounds unsweetened condensed skim-milk.

$\frac{13 \cdot 94}{21}$ of $50 \cdot 5 = 33 \cdot 52$ pounds skim-milk.

The unsweetened condensed skim-milk contains 30 per cent milk solids not fat and will therefore supply 30 per cent of 16·98 = 5·09 pounds milk solids not fat. The skim-milk will supply 9 per cent of 33·52 = 3·02 pounds milk solids not fat.

Tabulating the mix gives the following:—

Materials Used	Butterfat	M.S.N.F.	Sugar	Gelatin
35·0 lb. cream, 40 per cent fat	14·0	1·89		
16·98 lb. unsweetened condensed skim-milk		5·09		
33·52 lb. skim-milk		3·02		
14·0 lb. sugar			14·0	
0·5 lb. gelatin				0·5
100·00 lb. total mix	14·0	10·0	14·0	0·5

EXAMPLE IV.—A mix of 100 pounds is required to be made from the following materials: cream containing 30 per cent butterfat; whole milk containing 3·5 per cent fat; dry skim-milk containing 96 per cent milk solids not fat; sugar and gelatin.

The desired composition of the mix is as follows:—

13·5 per cent butterfat.
10·0 per cent milk solids not fat.
15·0 per cent sugar.
0·5 per cent gelatin.

Calculate first the pounds of butterfat, milk solids not fat, sugar and gelatin required.

13·5 per cent of 100 pounds = 13·5 pounds butterfat.
10·0 per cent of 100 pounds = 10·0 pounds milk solids not fat.
15·0 per cent of 100 pounds = 15·0 pounds sugar.
0·5 per cent of 100 pounds = 0·5 pound gelatin.

In this mix no sugar is added in the milk products, so the amount of sugar has already been determined and is 15 pounds. The gelatin has been determined also and is 0·5 pound. The amount of cream and whole milk to use is not calculated until the amount of dry skim-milk has been determined.

It is estimated that approximately half the milk solids required should be supplied by the dry skim-milk. As 10 pounds of milk solids not fat are required, 5 pounds will be supplied by the dry skim-milk which contains 96 per cent milk solids not fat. Therefore the pounds of dry skim-milk used will be

$$\frac{5}{96} \times 100 = 5{\cdot}2 \text{ pounds dry skim-milk.}$$

In order to find out if this is the proper amount of dry skim-milk to use, determine the pounds of cream and milk necessary to add, which is 100 — 20·7 (the pounds of mix already supplied) = 79·3 pounds.

The cream and milk supply 13·5 pounds of butterfat so that there will be 79·3 — 13·5 = 65·8 pounds of milk serum added also.

The milk serum has about 9 per cent of milk solids not fat, so it will add to the mix 9 per cent of 65·8 = 5·92 pounds of milk solids not fat. This amount added to the milk solids not fat supplied by the dry skim-milk (5·0 pounds) makes a total of 10·92 pounds of milk solids not fat, which is 0·92 pound more than required. It will therefore be necessary to reduce the quantity of dry skim-milk added to 0·92 ÷ 96 x 100 = 0·95 pound.

This leaves 5·2 — 0·95 = 4·25 pounds of dry skim-milk to be added. The extra cream and milk will contain some milk solids not fat but the amount will be so small as to be of no practical significance.

The 4·25 pounds of dry skim-milk will supply 96 per cent of 4·25 pounds = 4·08 pounds milk solids not fat.

The total amount of mix is now 4·25 pounds of dry skim-milk + 15 pounds of sugar + 0·5 pound of gelatin = 19·75 pounds, which leaves 100 — 19·75 = 80·25 pounds of the mix to be supplied by the cream and milk.

The amount of the milk solids not fat supplied by these two products is now calculated as previously.

80·25 pounds of cream and milk — 13·5 pounds fat = 66·75 pounds milk serum.

9 per cent of 66·75 pounds = 6·0 pounds milk solids not fat.

The milk solids not fat of the cream and milk (6·0 pounds) added to that of the dry skim-milk (4·08 pounds) make 10·08 pounds which is close enough to the required amount for all practical purposes.

The next step is to find the proper proportions of cream and milk to supply the 13·5 pounds of fat that are required. The total amount of these two products to be supplied is 80·25 pounds which must contain 13·5 pounds fat, so the cream and milk must be standardized to a test of

$$\frac{13{\cdot}5}{80{\cdot}25} \times 100 = 16{\cdot}82 \text{ per cent butterfat.}$$

Using Pearson's formula we have

Cream 30 per cent		13·32 parts of cream
	16·82 per cent	
milk 3·5 per cent		13·18 parts of milk
		26·50

Therefore the pounds of cream and milk to add will be as follows:—

$$\frac{13 \cdot 32}{26 \cdot 50} \text{ of } 80 \cdot 25 = 40 \cdot 34 \text{ pounds of cream.}$$

$$\frac{13 \cdot 18}{26 \cdot 50} \text{ of } 80 \cdot 25 = 39 \cdot 91 \text{ pounds of milk.}$$

40·34 pounds of 30 per cent cream supplies 12·1 pounds of fat.
39·91 pounds of 3·5 per cent milk supplies 1·4 pounds of fat.

This makes a total of 13·5 pounds of fat required. In tabulated form the mix will be as follows:—

Materials used	Butterfat	M.S.N.F.	Sugar	Gelatin
40·34 lb. cream, 30 per cent fat	12·1	6·00	....	....
39·91 lb. milk, 3·5 per cent fat	1·4			
4·25 lb. dry skim-milk	....	4·08	....	....
15·00 lb. sugar	....	....	15·0	....
0·50 lb. gelatin	....	....	....	0·5
100·00 lb. mix	13·5	10·08	15·0	0·5

EXAMPLE V.—A mix of 100 pounds is required and is to be made from unsalted butter containing 84 per cent butterfat; dry skim-milk containing 96 per cent milk solids not fat; sugar; gelatin and water.

The composition of the mix is to be as follows:—

Butterfat	15·0	per cent.
Milk solids not fat	10·5	"
Sugar	14·0	"
Gelatin	0·5	"

As in previous examples, the first step is to calculate the pounds of each ingredient that is necessary for a mix of this composition.

15·0 per cent of 100 = 15·0 pounds butterfat.
10·5 per cent of 100 = 10·5 pounds milk solids not fat.
14·0 per cent of 100 = 14·0 pounds sugar.
0·5 per cent of 100 = 0·5 pound gelatin.

The amounts of sugar and gelatin, as calculated, are 14 pounds and 0·5 pound respectively, and constitute 14·5 pounds of the total mix.

The butter, containing 84 per cent fat, supplies all the fat in the mix, so the amount of this product to use is determined as follows:—

$$\frac{100}{84} \times 15 = 17 \cdot 86 \text{ pounds butter.}$$

The dry skim-milk contains 96 per cent milk solids not fat and supplies all of the 10·5 pounds of this ingredient to the mix, as the milk solids not fat in the butter is negligible. The amount of dry skim-milk to add will be therefore:—

$$\frac{100}{96} \times 10 \cdot 5 = 10 \cdot 94 \text{ pounds dry skim-milk.}$$

The total number of pounds in the mix is now as follows:—

Butter	17·86 pounds
Dry skim-milk	10·94 pounds
Sugar	14·00 pounds
Gelatin	0·50 pound
Total	43·30 pounds

The remainder of the mix is made up by the addition of water which is $100 - 43 \cdot 3 = 56 \cdot 7$ pounds.

The tabulated mix is as follows:—

Materials used	Butterfat	M.S.N.F.	Sugar	Gelatin
17·86 lb. butter, 84 per cent fat	15·0			
10·94 lb. dry skim-milk		10·5		
14·00 lb. sugar			14·0	
0·50 lb. gelatin				0·5
56·70 lb. water				
100·00 lb. mix	15·0	10·5	14·0	0·5

The above is not an ideal mix but it is given to illustrate how such materials may be used when the supply of fresh sweet cream is not adequate. Such a mix could only be made by the use of an homogenizer or viscolizer to reconstitute the milk products into cream.

The examples of mixes as given might not be satisfactory to many ice cream men, and are only intended to show how a mix is calculated when using the different milk products that are commonly utilized in the commercial manufacture of ice cream. If these examples are studied and thoroughly understood, it will not be difficult for any maker to calculate a mix of any desired composition from any of the milk products used. The mixes calculated above only show the ingredients in the basic mix to which flavouring materials must be added.

When bulky flavouring materials such as various fruits, ginger, caramel, maple and chocolate are used, the proportions of the various ingredients in the ice cream mix are changed due to the dilution that takes place. These materials reduce the percentages of fat and milk solids not fat according to the amounts added as flavouring. For example, the addition of 5 per cent of strawberries to a mix containing 13 per cent fat and 11 per cent milk solids not fat reduces the fat content to 11·7 per cent and the milk solids not fat to 9·9 per cent. With chocolate syrups the dilution is greater. The decrease in fat content is not important, as long as the fat content remains above the legal requirements for fruit ice cream, but the reduction of milk solids not fat is likely to cause some difficulties with the texture of the ice cream in the form of iciness and coarseness.

There are two methods by which this dilution of the ice cream mix may be overcome, in so far as it affects the milk solids not fat. A special mix may be made with an increased percentage of milk solids not fat, or according to George (15) the milk solids not fat may be restored to the original percentage by calculating the amount of the dilution and adding a good quality skim-milk powder at the freezer when commencing to freeze. This is done by making a funnel of a piece of paper (a brick wrapper) and placing it into the opening at the front of the freezer. The skim-milk powder goes into solution quickly and it was found that stabilizing the milk solids not fat in this manner improves the texture and body of the finished ice cream and is a help in the production of a uniform ice cream with all flavours.

Processing the Ice Cream Mix

By the term processing is meant operations such as mixing the different materials, pasteurizing, homogenizing, cooling, ageing, freezing and hardening of the mix, which are used in the manufacture of ice cream. The first step in the processing is the mixing together of the various materials. There are many variations possible in the details of preparing a mix, which will give equally good results. This operation is carried out in a coil vat or mixing vat equipped with mechanical agitators, in which the mix is also pasteurized.

The common procedure is to add first the fluid milk products to the vat, then the dry milk products, if any are used, and lastly, the sugar and gelatin or other stabilizers and fillers. Colouring materials and flavours are added just before the mix is run into the freezers or sometimes after the batch is in the freezers. When crushed fresh fruits, nuts or other like materials are used for flavouring, these are added after the ice cream is partially frozen in the freezer.

Some ice cream men prefer to mix the dry milk products with two or three times their weight of fluid milk and heat to a temperature of 150° F. or over, before adding the balance of the materials. The whole is then pasteurized. Another method is to mix the milk powder with the sugar and add the two together to the fluid standardized cream. The main factor in the preparation of the mix is to see that all materials are thoroughly mixed and dissolved before pasteurization.

The method of adding the gelatin will depend largely on the form in which it is used. If it is in shreds or sheets it will be necessary to first dissolve it in water and heat it to a temperature of about 160° F. If gelatin is treated in this way it is made up in a 10 per cent solution of water and added just before pasteurization. If gelatin is used in the powdered form it may be thoroughly mixed with the sugar first, and added to the mixing vat in this way. Probably the simplest way to add the gelatin is to sprinkle it evenly over the cold mix and allow it to soak for a few minutes before pasteurization is commenced. Either of these methods of adding gelatin gives satisfactory results.

To obtain uniform results in the standardization of the mix, it is very essential that all ingredients be carefully weighed according to the amount of the mix to be prepared. There should be no guesswork as to the amounts of the different materials used, both for the sake of quality and uniformity of product and economy.

PASTEURIZATION

As in other branches of the dairy industry, pasteurization is one of the most important operations in the manufacture of ice cream, and is now compulsory. It protects the consumer by destroying any pathogenic bacteria that may have found their way into the raw materials, and improves the keeping quality of the mix and ice cream by destroying the greater percentage of the total bacteria present. Pasteurization also puts the mix in the best possible physical condition for homogenization or viscolizing.

The temperature for pasteurizing the ice cream mix should not be less than 145° F. for thirty minutes, or the equivalent. It is necessary also to obtain a thorough heating of every part of the mix for the full thirty minutes with this temperature, or pasteurization may be ineffective in destroying possible pathogenic contamination. The ice cream mix contains such a high percentage of total solids that it is more difficult to obtain thorough pasteurization than with milk. Some manufacturers therefore think it expedient to use a temperature of 150° F. for thirty minutes to ensure a margin of safety. Still higher temperatures for shorter holding periods may be used, but when the gelatin is added to the mix before pasteurization, temperatures over 160° F. are not advisable as the gelatin loses some of its gel strength under these conditions.

The chief purpose of pasteurization, which is the production of a safe and heathful article of food, should be borne in mind, and temperatures and holding periods used that will ensure such a product.

HOMOGENIZATION

The purpose of this process is to produce a homogeneous mix in which all ingredients are finely divided and thoroughly distributed. There are different types of machines on the market for this purpose called homogenizers, viscolizers, or emulsifiers. Although these machines are of somewhat different mechanical construction, they produce practically the same effect on the mix. The mix is forced through a very small valve under high pressure by means of cylinder pumps. This breaks up the fat globules into smaller ones and distributes them evenly through the whole mix, and thereby increases viscosity. The other ingredients also are finely divided and distributed, making a smoother mix which is more easily controlled in the freezing process.

Homogenization of the mix is carried out immediately after pasteurization at pasteurization temperatures. Homogenization at temperatures of 145° to 150° F., rather than at lower temperatures, tends to lessen clumping of the fat globules which improves the whipping ability of the mix. No definite statement can be given in regard to homogenizing pressures for best results, but under average conditions for commercial ice cream mixes, pressures of 2,500 to 3,500 pounds are generally used with a single-stage machine. For the two-stage homogenizer, pressures of 2,000 to 3,000 pounds are commonly used for the first stage and 800 to 1,500 pounds for the second stage.

Some of the factors which should be taken into consideration in determining the homogenization pressure to use are the acidity and composition of the mix, the homogenizing temperature used, and the condition of the homogenizer itself.

The chief advantages of homogenization may be listed as follows:—

(1) It increases the whipping qualities of the mix.
(2) It gives greater uniformity of texture and body to the ice cream.
(3) It increases palatability and apparent richness.
(4) It makes it possible to attain more uniform overrun and to retain it in the frozen ice cream.
(5) It lessens the danger of churning during freezing.
(6) It makes possible the use of butter and powdered milk products to reconstitute cream when there is a shortage of sweet cream.

COOLING

From the homogenizer the mix is immediately cooled to a temperature of 40° F. or lower. This is generally done over an open tubular cooler by the use of water in the top section and brine in the bottom section. In a small plant where there is no homogenizer, the mix may be cooled in the same vat in which it is mixed and pasteurized.

The cooler should have sufficient capacity to cool thoroughly all the mix as it leaves the homogenizer to at least 40° F. The open cooler should be placed in a clean, dust-free room or serious recontamination of the mix may occur.

AGEING THE MIX

The ice cream mix is usually aged or held at low temperatures before freezing. Previously the mix was allowed to age for two or three days or longer, as it was thought that this produced a high viscosity which gave a better product. It has now been demonstrated that the benefits of ageing can be obtained in four to twelve hours, and that ageing more than twenty-four hours does not bring any decided improvement in the quality of the ice cream.

Investigations by Sommer (5) showed that unaged mixes are likely to fail to produce the desired overrun, and that ageing decreased the time required to get 100 per cent overrun and increased the maximum overrun obtained.

It is advisable to age the mix for two to four hours but twenty-four hours is ample time to derive all the benefits of ageing. The temperature of ageing should be below 40° F., and as low as 32° F. is quite safe. Such low temperatures will effectively control bacterial growth and acidity in the mix.

FREEZING

One of the most important steps in the manufacture of ice cream is the freezing process. This is purely a mechanical operation, but the ice cream maker should thoroughly understand what takes place during freezing if the best results are to be obtained in quality and quantity in the finished ice cream. Freezing is also an important operation from an economic standpoint, as careless work may reduce overrun to such an extent that serious loss in output may result. Furthermore, a thorough knowledge of the mix and freezing process may reduce the time necessary to freeze each batch by several minutes, which would naturally increase the capacity of the plant.

Modern commercial freezers are made in the form of a refrigerated cylinder, both horizontal and vertical, in which are placed mechanical devices for whipping and scraping the mix from the cold surface of the cylinder walls as it becomes frozen. The most commonly used freezer is the horizontal type and may be purchased in capacities ranging from 40 to 160 quarts. The refrigeration is supplied by either brine or the direct expansion of ammonia in an enclosed jacket which surrounds the freezing chamber. In the more commonly used brine freezers the construction is such that the brine flows through a regular channel from the inlet to the outlet and comes in contact with the whole surface of the inner jacket.

In recent years several makes of continuous freezers have been put on the market. With this type of freezer the mix and air are propelled through the freezing chamber in controlled proportions by means of pumps, and continuous freezing of the mix takes place.

During the freezing process the mix is partially frozen and at the same time air is whipped into the frozen mix to produce a smooth texture, good body and a moderate amount of overrun in the finished product. After the mix enters the freezer it is first cooled down to the freezing point, which is approximately 27° F., depending on the composition of the mix, and then the water in the mix begins to freeze out in the form of ice crystals. After the mix is frozen to the proper stiffness, which is best determined by observation and judgment, the brine or other refrigerant is shut off and the semi-frozen mix is then whipped to the overrun desired. The ice cream which is of semi-solid consistency is then drawn from the freezer at a temperature which may range from 21° to 25° F.

Many investigations on freezing ice cream have shown the following factors to be most important:—

(1) The composition of the mix.
(2) The temperature of the mix as it enters the freezer.
(3) The temperature of the brine.
(4) The volume or rate of flow of the brine.
(5) The speed of the dashers.
(6) The method of processing the mix.
(7) The fullness of the freezer.

The composition of the mix influences the freezing point, which in turn affects the rate and time of freezing. A high fat content in the mix tends to raise the freezing point, while sugar depresses the temperature at which ice

cream freezes. A mix with a high percentage of sugar will take longer and be more difficult to freeze and keep frozen. The man in charge of the freezer should know the composition of the mix to get the best results possible.

The temperature of the mix also influences the rate and time of freezing. If the mix has a high temperature when it enters the freezer, it requires more refrigeration to cool to the freezing point and also a much longer time. With an improperly processed mix this may result in churning which is not only detrimental to quality, but decreases the overrun considerably as viscosity is lessened to such an extent that the mix will not retain the incorporated air. A good mix may take so long to reach the freezing point that the whipping will be prolonged and air beaten out of the mix instead of in it. This may result in large ice crystals in the ice cream which give a coarse texture. The mix should enter the freezer at a temperature as near 32° F. as possible to give the most satisfactory results.

The temperature of the brine, the volume or rate of flow of brine through the freezer and the speed of the dashers are three factors that are very closely related in the freezing process. The speed of the dashers has been thoroughly studied by manufacturers of freezing equipment, and is so regulated that this factor need cause little worry or trouble. The temperature of the brine is important, however, and is under control of the freezer operator.

While previous investigations (16, 17, 18) indicated that brine temperatures of 0° to 14° F. were satisfactory for freezing ice cream, recent experimental work has shown that temperatures from 0° to —10° F. are more desirable. These lower brine temperatures permit of faster freezing of the mix and lower drawing temperatures, factors which are conducive to a smoother textured ice cream because the water is frozen in smaller ice crystals. The pressure and volume of the brine are also important factors in proper freezing. The brine should have a pressure of 10 to 15 pounds at the freezer inlet and the volume of brine flowing through the freezer should be sufficient so the outgoing brine will not be more than 5° F. higher in temperature than the incoming brine.

When a low temperature brine is used care should be taken to see that the ice cream is not frozen so stiff that it is difficult to obtain the desired overrun in a reasonable time, or the texture of the ice cream is likely to be coarse. High brine temperatures increase the time necessary for freezing and whipping and set up conditions that are not conducive to best quality product.

For good freezing results, the freezer should be filled only half full to allow for proper overrun, and the scrapers and dashers should be in good mechanical condition. The scraper blades should be kept sharp and even so that they will scrape off the frozen mix from the refrigerated walls of the freezing chamber as soon as it forms.

OVERRUN OR SWELL IN ICE CREAM

The overrun or swell in ice cream that occurs during the freezing process may be calculated either by volume or by weight. If the overrun is calculated on a volume basis, it is equal to the difference between the volume of the mix used and the volume of the ice cream frozen. The formula for computing overrun on the volume basis is as follows:—

$$\frac{\text{Volume of ice cream obtained} - \text{volume of mix}}{\text{volume of mix}} \times 100$$

There is a tendency at the present time, however, to figure the overrun on the basis of weight. The weight of finished ice cream is much less than the same volume of mix due to the incorporation of air during the whipping.

The formula for calculating the percentage of overrun on the weight basis is as follows:—

$$\text{Percentage overrun} = \frac{\text{The weight of unit volume of mix} - \text{the weight of unit volume of ice cream}}{\text{The weight of unit volume of ice cream}} \times 100$$

Thus, if the weight of one gallon of mix is 10·8 pounds and the weight of one gallon of the ice cream is 6 pounds, the percentage overrun would be equal to

$$\frac{10 \cdot 8 - 6}{6} \times 100 = 80 \text{ per cent.}$$

The amount of overrun has a marked influence on the body and texture, and therefore the general quality of ice cream. A low overrun results in a heavy, soggy ice cream which is coarse in texture, while too great an overrun with average ice cream produces a body that is light and fluffy and the frozen ice cream melts readily and shrinks excessively when dipped from the can.

The proper amount of overrun is a much debated question and will depend a great deal on the composition and method of treating the mix. For example, a mix containing a high percentage of milk solids not fat will allow of greater overrun than mixes of low milk solids not fat. Generally an overrun of approximately 90 to 100 per cent will be found satisfactory. But manufacturers should decide on the overrun best suited to the composition of their mixes and other conditions, and then try to keep to the standard set.

The volume of overrun is influenced by many factors, the chief of these being:—

(1) The composition and preparation of the mix.

(2) The manner of freezing.

While the composition of the mix is known to have a definite effect on whipping ability and overrun, the results of investigational work show some divergence of opinion as to the influence of the various ingredients in the mix. In general, however, it has been found that different percentages of fat within the range of good commercial mixes have little influence on overrun, but that the source of the fat is more important. When fat is supplied in the form of fresh cream the whipping ability of the mix is better than when butter or frozen cream is used. Milk solids not fat between 8 and 12 per cent have little effect on overrun and whipping ability, but it has been shown that the form in which the solids are found has a greater influence on whipping ability than the amount. Sugar is a deterrent to overrun and gelatin has also been found to retard and lower overrun as the amounts used were increased. The importance and advantages to the texture of the finished ice cream by the use of moderate amounts of gelatin more than offset any disadvantages as regards overrun. Egg solids improve whipping ability and overrun even when added in quantities of 0·25 to 0·5 per cent in the form of powdered egg yolk.

Homogenization increases overrun and improves whipping ability, as does ageing the mix for periods of four to twenty-four hours at temperatures of 32° to 40° F. The heat treatment of the milk products also has an influence on whipping ability. As the temperature of pasteurization and homogenization is increased up to 170° F. the whipping ability of the mix is improved, but there are other limiting factors of a practical nature to such high temperatures.

Good freezing practices are conducive to good overrun. Overrun may be limited by freezing the mix too quickly and too stiff as well as by freezing too soft. The speed of the dasher and scrapers, over- or under-loading the freezer, dull scraper blades, and the type and design of the freezer are all contributing factors to the amount of overrun obtainable and the time necessary to obtain overrun.

HARDENING THE ICE CREAM

As the ice cream leaves the freezer in a semi-solid condition, it must be hardened before being sold for consumption. The ice cream is drawn from the freezer into pack cans and then placed in a hardening room cooled by mechanical refrigeration or packed in ice and salt in a hardening cabinet or box. The pack cans should be cooled before being filled with the soft ice cream, or the warm cans melt the ice cream that comes in contact with the cans, which produces ice crystals. In many plants the pack cans are lined with a waxed or parchment paper which protects the ice cream from coming in contact with cans that may be the worse for wear.

Where mechanical refrigeration is used, there are two main types of hardening room, the still air type and the forced air type. In the still air type the room is cooled by direct expansion coils or coils containing brine, which are usually piped so they form shelves on which the ice cream cans are placed. In the forced air hardening room the expansion or brine coils are placed near the ceiling and the cold air may be circulated by gravity or by the use of fans. The temperatures of hardening rooms may range from 0° to — 20° F. and should be kept as uniform as possible. A period of twelve to twenty-four hours should be allowed to harden 5-gallon cans of ice cream, depending on the temperature of the room.

New developments have been introduced to produce what is termed "Fast Frozen" ice cream. By means of low temperatures of — 25° F., and sometimes as low as — 30° to — 40° F., and a vigorous circulation of the cold air around the cans by means of fans, the time of hardening can be reduced to about one-third. This rapid hardening of the ice cream results in a smoother texture in the finished product, because the water is frozen in smaller crystals than would ordinarily be the case.

The introduction of electrically operated refrigerating cabinets and small freezers has practically eliminated the use of the ice and salt hardening cabinets. Where it is still necessary to use ice and salt for hardening the ice cream, the cabinet should be made of heavy plank and watertight, with a hole near the bottom from which the brine may be drawn. Crushed ice to a depth of 4 to 6 inches is placed in the bottom of the tank and after the cans are placed in the tank it is filled up with ice and salt. Most of the salt should be placed in the upper third of the ice, so that it will run down over the rest of the ice as it comes into solution. The cans should be covered to a depth of 4 to 6 inches with ice and salt and left to harden. One pound of salt to 5 or 6 pounds of ice make a good freezing mixture. If the ice cream is stored in the box for any length of time, it should be repacked at least twice a day to keep it thoroughly hardened.

Ice Cream Defects

In common with other food products, all ice cream does not come up to the ideal quality for the product. This ideal varies more than other dairy products, due to individual preferences in taste and to the many flavours used in the manufacture of ice cream. But there are certain defects, fairly well defined, that occur in ice cream because of inferior flavouring materials, the use of poor quality products, or improper methods of manufacture.

The common defects that occur in ice cream may be grouped as follows:—

(1) Flavour defects.
(2) Defects of body and texture.
(3) Defects in richness.
(4) Defects in colour, appearance and package.

There are several gradations of defects in flavour. The least serious are those due to the use of too much or too little sugar and too much or too

little flavouring materials. These defects are due to individual tastes and can easily be controlled by the ice cream maker who studies the preferences of his customers.

The more serious flavour defects in ice cream are due largely to the use of poor quality dairy products. Off flavours in dairy products may be due to feed or absorption of foreign odours and flavours, bacterial and chemical changes and contamination by foreign substances. Such flavours as bitter, salty, rancid, unclean, sour, fruity and metallic may be caused by one or more of the above factors. Other undesirable flavours may be due to the use of too much powdered or condensed milk products and egg powder, especially if these are not of the highest quality. Close supervision of all materials to eliminate those of poor quality, and the use of clean equipment in good condition will eliminate most flavour defects.

The common terms used to describe defects in body and texture are as follows: weak or fluffy, soggy, icy, coarse, buttery and sandy. Such defects are due to an improperly balanced mix and poor methods of manufacture. Weak or fluffy body and texture is caused by too low a percentage of milk solids not fat, too little gelatin or other stabilizer, or by too great an overrun. Such an ice cream melts too readily and shrinks excessively when dipped from the can. A coarse texture and body lacks smoothness to the tongue and may be due to a lack of milk solids not fat or of gelatin, or may be caused by drawing the ice cream from the freezer when it is too soft. These conditions are conducive to the formation of large air cells during whipping which break down and permit the formation of ice crystals. An icy texture and body results from the same conditions as the coarse texture and is characterized by the presence of large ice crystals that are definitely noticeable to the tongue.

Soggy ice cream is heavy and oftentimes sticky, and is caused by the use of too much solids not fat or total solids and by not freezing to give sufficient overrun.

Sandiness in ice cream should not be confused with the defect caused by the formation of excessive ice crystals. Sandy ice cream has a sort of gritty texture caused by the crystallization of the lactose or milk sugar in the ice cream. This trouble usually develops after hardening, as milk sugar is more soluble in warm solutions than in cold. Sandiness may develop in ice cream that has too high a content of total solids or milk solids not fat, which gives an excessive amount of milk sugar to the mix. Alternate softening and hardening will often bring on sandiness in ice cream when there is a high proportion of total solids. The remedy is to proportion carefully the mix so that the concentration of milk sugar will not be too great. It is generally considered that 12 per cent is the maximum amount of milk solids not fat that may safely be used.

Other defects are those due to unnatural colouring in the ice cream or poor package which detracts from the appearance of the finished product.

A Score Card for Ice Cream

For the purpose of comparing the quality of ice cream samples at competitions, it is necessary to have a guide, which is best supplied by a score card. Many suggestions have been put forward, but up to the present there is no official score card for ice cream, as there is for butter and cheese. The main points that have been considered on ice cream score cards used by dairy departments at various agricultural colleges and in connection with competitions are as follows: flavour, body and texture, richness, permanency, colour, package, and bacterial content.

The highest quality ice cream should have a clean, creamy flavour, a firm, smooth and velvety body and texture, and natural colour for the flavouring material used. It should comply with the legal standards of the country in

which it is sold and be put up in clean neat packages, and should have a low bacterial count.

As in the case with other dairy products, flavour is the most important quality in ice cream. Body and texture are also important as they affect the palatability of the ice cream and influence the amount that is obtained from a given volume when dished out to individual consumers. In some score cards, the qualities of richness and permanency or the ability of the ice cream to withstand melting are given definite values. However, richness is controlled by legal standards and permanency is so linked up with body and texture that it is a question whether these characteristics should be considered individually. Colour and package are considered separately or together in judging ice cream and are allotted points commensurate with their importance.

Although some score cards do not take into consideration the bacterial content of ice cream, the more recent suggestions give this important matter a place in the score card, and rightly so. Of course the bacterial content of ice cream cannot be detected by the consumer, but must be determined by laboratory methods. In nearly all ice cream competitions, this is being done and the ice cream scored according to the laboratory records of bacterial counts.

The score card most commonly used at student judging competitions and for competitions of commercial ice cream is as follows:—

	Points
Flavour	50
Body and texture	25
Bacteria	20
Package and colour	5
	100

The Bacterial Content of Ice Cream

The increasing importance of ice cream as a food product makes it imperative that the quality of the ingredients, methods of manufacture and the cleanliness of plant and equipment should be carefully controlled so that the bacterial count will be reduced to a minimum.

Manufacturers are realizing more and more the importance of high quality ingredients and cleanliness of plant, equipment, and personnel in the production of ice cream that will inspire the confidence of the consuming public. There is just as great a necessity for controlling the manufacture of ice cream from a sanitary standpoint as with the production and processing of market milk or other food supplies.

For this reason bacteriological examinations of ice cream are receiving more attention as they afford the best means of indicating the quality of products, the methods of manufacture, and the cleanliness of plant and equipment. Many of the larger ice cream plants are now carefully controlling all their operations by means of bacterial counts and find them a very important aid in the production of a high quality ice cream.

The necessity of careful sanitary control in the manufacture of ice cream is recognized by the establishment of regulations under the Food and Drugs Act, which provide for the compulsory pasteurization of the ice cream mix and a bacterial standard of not more than 100,000 per gram.

There are very few published data on the bacterial content of ice cream in Canada. James (12) in a study of uniformity of ice cream found that the bacterial counts of 28 samples of commercial ice cream from 9 plants ranged from 4,000 per gram to 670,000 per gram. At an ice cream scoring competition 64 samples had counts ranging from 700 to 1,500,000 per gram.

Unpublished data obtained from the bacteriological examination of over 800 samples of Canadian ice creams in the laboratory of the Division of Bacteriology and Dairy Research show that the bacterial counts ranged from 500 to 50,000,000 per gram. Approximately 49 per cent of the samples, however, had bacterial counts of less than 100,000 per gram. Many plants were producing ice cream which had a low count consistently, while ice cream from other plants had high bacterial counts consistently or counts that were variable.

The data on the bacterial content of Canadian ice creams are similar to those obtained from a number of studies of the bacterial content of ice cream in the United States. In some early investigations, Hammer (19) reported on samples examined during the years 1905-1912 and showed counts for ice cream from different cities averaging from 1,800,000 to 26,612,371 per gram, with a maximum count of 8 billion per gram.

Ayers and Johnson (20) reported on a study of retail ice cream during summer and winter months with average counts for the summer of 37,859,907 and for the winter of 10,388,222 bacteria per gram.

More recent investigations by Fay (21), Olsen and Fay (22), and Fabien (23) show, however, that many samples of ice cream have counts below 50,000 and 100,000 and that it is quite possible to produce ice cream on a commercial scale with counts of less than 100,000 bacteria per gram.

Sources of Bacteria in Ice Cream

Investigations (22, 24) by several authorities have shown that there are three main sources of bacteria in ice cream, namely, from the materials used, from the equipment, and from persons handling the products during manufacture. These investigations demonstrate that the milk and cream used in the mix are the most important sources of bacteria. Other milk products such as condensed and powdered milk and butter may also be a contributing factor to high counts if they are not of good quality.

Gelatin may be a source of large numbers of bacteria, but the better grades are so carefully prepared that gelatin should not be a troublesome factor. Hood and White (8) found that most gelatins on the market in Canada contained few bacteria, and their addition to the ice cream mix would make no appreciable difference to the total bacterial count. Under regulations of the Food and Drugs Act (January 18, 1936) edible gelatin shall contain not more than 10,000 bacteria per gram, so that this material should not be a significant factor in bacterial counts of ice cream. Sugar and flavouring extracts are not important as a source of bacteria when properly cared for in the plant. Smallfield (25), however, has shown that liquid colouring materials as prepared in ice cream plants may be a source of bacterial contamination of significant proportions unless proper precautions are taken during preparation.

Flavouring materials such as fruits or nuts which are added at the freezer, may be additional sources of bacteria in ice cream of some importance unless they are packed and handled under sanitary conditions.

However, as milk, cream and other dairy products are the main sources of bacteria in ice cream as far as ingredients are concerned, the use of good quality products and proper pasteurization will ensure a low bacterial count in the basic mix. After pasteurization, therefore, the ice cream manufacturer usually starts out with a mix that is satisfactory from the standpoint of bacterial counts.

Under these conditions a high count in the finished ice cream indicates contamination from the equipment or inefficient methods of processing the mix. The homogenizer, cooler, and freezer may be fertile sources of recontamination unless these pieces of equipment are kept scrupulously clean and are sterilized each day after using. During homogenization and freezing there is usually an

increase in numbers of bacteria present due either to unclean conditions or probably the breaking up of clumps of bacteria during the process. But if the equipment is thoroughly sterilized, the increase will be negligible, and these operations will not be a factor in high counts.

In the manufacture of ice cream, it is of the utmost importance that the personnel of the plant be particular regarding personal cleanliness and habits. The danger of contamination from such sources lies in the possibility of introducing into the product pathogenic bacteria after pasteurization. This is a matter that should receive the greatest attention from managers and employees at all times. The handling of the product after pasteurization and of the materials that are not pasteurized should be done with great care and precaution.

Cleaning Ice Cream Equipment

If the ice cream manufacturer would produce a high quality product containing a low bacterial count, the equipment in the plant must be given careful and conscientious attention at all times. This is one of the most important factors in the production of low-count ice cream, for investigations have shown that pasteurization destroys nearly 99 per cent of the bacteria in the raw materials. If equipment is not thoroughly cleaned and sterilized, recontamination of the pasteurized mix is inevitable and high bacterial counts are the result.

In cleaning the ice cream equipment, the common good practices of washing and sterilizing dairy utensils should be employed. The equipment should first be rinsed thoroughly with cold or lukewarm water. Hot water should never be used for the first rinsing because of the high content of milk solids not fat in the mix which are burnt on to the equipment when hot water is used first. After the first rinse, the machines should be washed with hot water containing a good alkali washing powder. Then, if possible, the machines should be thoroughly scrubbed with a good bristle brush to remove particles of the mix. Cloths or rags should never be used to wash dairy utensils and equipment. After scrubbing, the equipment should be given a thorough rinse with clean hot water, to remove any traces of the alkali wash water and then thoroughly sterilized.

In sterilizing dairy utensils and equipment, the best means is by the use of steam or boiling water. The efficiency of the sterilization will depend on the degree of heat imparted to the equipment and the length of time applied. Small utensils are best sterilized in a sterilizing cabinet where steam can be applied under a few pounds pressure. With mixing vats, open tubular coolers and other equipment this is not possible, but a means should be found to use steam or boiling water for such equipment.

Sanitary pipe lines should be taken apart and thoroughly washed and brushed after use and then steamed for about five minutes. The homogenizer should be taken apart and the valves and other parts thoroughly scrubbed and sterilized by means of steam. If particular care is not given this machine, it offers a very likely source of recontamination to the ice cream mix.

The freezer will require special care in washing and sterilizing. The machine will be so cold after operation that very hot water should only be applied after several rinsings with water that has been gradually raised in temperature. Otherwise the freezer will be subjected to such a strain in the expansion and contraction of the linings that leaks may appear or the inner cylinder may even be distorted. The mechanism should not be run excessively during washing as this dulls the scraper blades. After the mix has been completely rinsed out, the freezer should be washed with an alkaline washing solution at a temperature of about 100° F. and then rinsed with clean water at the same temperature. Sterilization may be done by rinsing with warm water

containing 30 to 50 parts per million of available chlorine. Care should be exercised in using very hot water in direct expansion freezers due to the excessive ammonia pressure that may be developed.

The pack cans should also receive careful washing and sterilization, and should always be placed in a clean, dry place after sterilization.

Carelessness in the cleansing of equipment is inexcusable in any dairy plant and especially so in connection with the manufacture of ice cream. With good quality materials, careful pasteurization, and clean equipment, ice cream can be produced under commercial conditions from day to day with much less than 100,000 bacteria per gram.

Testing Methods for Ice Cream

In order to control the composition of the ice cream mix and to keep down the cost of manufacture, it is very necessary that the ice cream maker should know the composition of the various ingredients which he uses as well as the final composition of the mix. He is able then to make up a mix of any desired composition, and keep it uniform from day to day. For the large commercial plant equipped with a laboratory and special apparatus, this work offers no serious difficulties. The small plant, however, cannot afford expensive equipment for testing purposes and must use other methods. But the question of checking the composition of the mix is just as important for one as for the other.

TESTS FOR BUTTERFAT

Equipment and glassware for making Babcock tests for fat are usually found in all dairy plants, and there have been several modifications of the Babcock method worked out that give satisfactory practical results with careful operation.

The following modifications of the Babcock test have been found to give satisfactory and sufficiently accurate results for practical use. The first of the tests given was submitted by Fisher and Walts (26) and the procedure is as follows:—

(1) Mix thoroughly the ice cream or ice cream mix.
(2) Weigh out 9 grams in a whole-milk test bottle.
(3) Add 10 c.c. of 95 per cent ethyl alcohol and shake thoroughly.
(4) Add 9 c.c. of sulphuric acid, specific gravity 1·82 to 1·83 and shake.
(5) Finish the same as for whole milk.
(6) Multiply reading by two.

NOTE.—Where ethyl alcohol cannot be obtained, rubbing alcohol has been found satisfactory.

Several sulphuric acetic acid modifications of the Babcock test have been proposed in which there are some differences in the strength and amounts of reagents used. The following test is suggested in the Laboratory Manual compiled by the International Association of Milk Dealers (27) and has been found by Smallfield (28) to give satisfactory results for plant tests.

(1) Weigh 9 grams of ice cream mix or thoroughly melted and mixed ice cream into an ice cream test bottle (20 per cent) or a milk test bottle.
(2) Add 13 c.c. glacial acetic acid and mix thoroughly.
(3) Add 9 c.c. commercial sulphuric acid and again mix thoroughly.
(4) Place the bottle in a water bath (at 170° F.) for five minutes.
(5) Remove, shake thoroughly and whirl bottles in a heated centrifuge for five minutes.
(6) Add soft water (180° F.) to the base of the neck of the bottle. Whirl again for two minutes.

(7) Add sufficient soft water (180° F.) to float fat in the neck of the bottle and whirl for one minute.
(8) Place bottles in water bath at 135°-140° F. for at least three minutes. Add a few drops of glymol (red or blue reader) and read with dividers. Multiply the reading by two to obtain percentage of butterfat if a milk test bottle has been used.

The following procedure with the sulphuric acetic acid test has been found to give good results by the Dairy Industry Department, Iowa State College of Agriculture (29).

(1) Weigh 9 grams of ice cream mix or thoroughly melted ice cream into a milk test bottle or ice cream test bottle (20 per cent).
(2) Add 8-10 c.c. of 80 per cent glacial acetic acid and mix thoroughly.
(3) Add 6-8 c.c. of concentrated sulphuric acid and mix thoroughly.
(4) Complete as for the regular Babcock test.
(5) Add glymol for reading the test.
(6) If a milk test bottle has been used multiply the reading by two.

The sulphuric acetic acid tests cannot be used with chocolate ice cream or ice cream mixes containing chocolate.

One of the more recent tests is that proposed by Crowe (30) and is recommended in the Laboratory Manual compiled by the International Association of Milk Dealers. In this test two reagents are used.

Reagent A.

90 c.c. Normal butyl alcohol.
10 c.c. Ammonium hydroxide (chemically pure).

Reagent B.

100 c.c. Sulphuric acid (specific gravity 1·82 to 1·83).
100 c.c. Ethyl alcohol (pure 95 per cent).

This reagent is mixed by carefully pouring the sulphuric acid slowly down the side of a beaker containing the alcohol. The container should be made of glass that will withstand high temperatures. The mixture is thoroughly stirred with a glass rod and cooled to room temperature before use. The reagent should be kept in a tightly stoppered glass bottle.

Procedure:

(1) Weigh 9 grams of well-mixed melted ice cream or ice cream mix into an 8 per cent milk test or ice cream test bottle by means of a Torsion cream test balance.
(2) Add 5 c.c. of reagent A, mix thoroughly by shaking.
(3) Add 30 c.c. of reagent B, or slightly less (28 to 29 c.c.) to just below the level of the bottle neck and shake thoroughly until all the curd is dissolved.
(4) Place the tests in a water bath between 175° and 180° F. for 15 minutes and shake at least three times during the heating.
(5) Centrifuge the bottle for 5 minutes at the usual Babcock test speed. Shake the contents of the bottle thoroughly after this centrifuging and, if necessary, add enough water at 180° F. to bring the level of the contents to the base of the neck. Centrifuge again for 3 minutes and shake again if any curd is apparent.
(6) Add water at 180° F. to bring fat column in the graduated neck and centrifuge for 1 minute.
(7) Place the bottles in a water bath at 135° to 140° F. for 5 minutes, add glymol, and read the tests as in a Babcock cream test.
(8) Multiply the reading by 2 when a milk test bottle is used.

TESTS FOR TOTAL SOLIDS

In addition to knowing the percentage of fat in the mix or finished ice cream, it is advantageous to know also the total solids in the mix. Modified tests for this purpose have been recommended and can be made with inexpensive equipment.

The following test was elaborated and is recommended by Prof. A. L. Gibson, and is known as the O.A.C.-Gibson Method for determining total solids in ice cream.

APPARATUS NECESSARY

1. Small electric hotplate with rheostat attachment for temperature control and furnished with mercury well.
2. Thermometer graduated to 250° C.
3. Balance, capacity 120 grams, sensitive to ·01 grams, with weights from 50 grams to 1 centigram.
4. Aluminum dish, diameter 4 inches, depth 1 inch.
5. Five-c.c. pipette.
6. Steel crucible tongs for lifting dishes.

PROCEDURE.—Heat the electric plate to a temperature of 190° C. The temperature is ascertained by placing the thermometer in the mercury well. Adjust the rheostat so as to maintain as near as possible a temperature of 190° C.

Warm the sample of ice cream in a water bath to a temperature of 70° C. and stir thoroughly before weighing. Accurately counterpoise the aluminum dish on the balance and with the 5 c.c. pipette weigh out exactly 5 grams of the sample into the dish. Add 3 c.c. of distilled water to the weighed sample and carefully mix so as to make a uniform film of liquid over the bottom of the dish. Place the dish on the electric plate at 190° C. and heat until the sample is a uniform chocolate brown colour. While the sample is being heated, adjust the rheostat so that the temperature will not fall below 180° C. during the heating process. Immediately after the heating process is completed cool the dish to room temperature under ordinary atmospheric conditions and accurately reweigh. The percentage of solids is estimated by multiplying the weight of solids left in the dish by 20.

Smallfield (28) has suggested some modifications of the above method which do not require the use of a hot plate with rheostat connections or a special balance. In the modified test, a 5-gram sample of ice cream mix or thoroughly melted ice cream is weighed on a cream test scale and the moisture is then evaporated off over a Bunsen burner or an alcohol lamp until the residue is a chocolate brown colour. While results with the modified test were not quite as accurate when compared to the Mojonnier as the hot plate method, the test was considered satisfactory for routine plant testing.

THE ACIDITY TEST

With a 9 c.c. pipette measure out 9 c.c. of the cream or mix to be tested in a white dish or cup. Rinse out the pipette with 3 or 4 c.c. of warm distilled water and deliver it in the cup. Add 3 to 5 drops of phenolphthalein indicator. From a burette graduated in tenths of cubic centimetres, add slowly a tenth normal solution of sodium hydroxide until a permanent faint pink colour appears. Read from the burette the number of cubic centimetres of alkali used and divide by 10 to obtain the percentage of acid in the mix.

If a ninth normal solution of sodium hydroxide is used, measure out 10 c.c. of mix and titrate. Divide the result by 10 to obtain the percentage of acid.

When possible, more accurate results are obtained if the material is weighed rather than measured. Use the same number of grams as cubic centimetres.

When larger quantities of cream or mix are used, the percentage of acid may be calculated from the following formula when n/10 alkali is used:—

$$\frac{\text{Number of c.c. of n/10 sodium hydroxide x.009}}{\text{number of c.c. or grams of sample}} \times 100 = \%\ \text{acid.}$$

Fuller details of this test may be had from Bulletin No. 138, New Series, of the Dominion Department of Agriculture, Ottawa.

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